A SURVEY OF MILITARY PERSONNEL COST MODELS

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THESIS

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ABSTRACT

The recent history and development of military manpower/personnel cost models is surveyed. The major models, in general those models not developed ad hoc, are traced in their development and examined for their consistency of logic. Both billet cost models and appropriation-oriented (budget) cost models are discussed with a sufficient background to discern their possible uses. In addition, a per capita cost model is proposed from the recently accepted billet cost model designed by B. K. Dynamics, Inc.

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I. INTRODUCTION

On 6 March 1967 the Honorable Robert S. McNamara, Secretary of Defense, directed the Secretary of the Navy to develop a manpower cost model to be used by the military in design trade-offs. The other military departments and agencies were "directed to provide information as needed."

Prior to this directive numerous starts had been made at producing some form of a military manpower/personnel costing model. Essentially these models fell into two broad categories, "billet costing models" and "appropriation-oriented (or budget) models." Billet costing models are loosely defined as those models designed to reflect those personnel costs required to fill and maintain the armed forces billets or jobs. Appropriation-oriented cost models are defined as those models used in budget planning. The models are significantly different. For example, values used in costing "downtime" of personnel in service schools and values that reflect the effect of "continuance rates" are not contained in personnel cost data for budgetary purposes. This paper will attempt to survey the recent history and growth of both types of models and offer criticism as the opportunity arises. Finally, a third type model, a per capita costing model, to be used in life-cycle costing of the manpower inventory will be proposed.

Personnel costing models are required for a variety of specific reasons. One primary reason often cited is to examine man-machine trade-offs in present and future weapons systems. For

example, suppose a new and sophisticated "black box" can be added to a present weapons system at a cost of X dollars with a resulting reduction in manning requirements of one technician, say a Sonar Technician First Class. The obvious question arises, "Is this a cost-effective (desirable) trade-off?" Similarly suppose this hypothetical "black box" instead of eliminating the requirement for a first class technician merely reduces the skill level required to operate and/or maintain the system so that now a third class technician can perform the job. What is the cost-effectiveness under these circumstances? An accurate billet cost model would help provide answers to these questions. Still further benefit can be achieved. In current systems analysis work it is often difficult when performing life-cycle systems costing to compare systems with differing personnel requirements. An acceptable billet cost model would allow the analyst to tag every billet within a system with a cost. In this way a more reliable comparison of systems can be achieved. In short, a billet cost model can be used to improve life-cycle costing and improve analysis of man-machine trade-offs.

Annually the Department of Defense requests certain dollars from Congress for military personnel costs. The Navy's congressional appropriation for personnel costs (less reserve personnel costs) is classified MPN, Military Personnel, Navy. How is the budget request for this appropriation formulated? Suppose Congress reduces the manpower ceiling; how much will this alter budget requests? Many similar questions can be answered by personnel cost models, specifically appropriation-oriented cost models.

Initial manpower cost models were limited to costs strictly associated with an individual armed force or at most with costs strictly within DOD funding. These neglected purposefully those costs incurred by other Government agencies. Agencies such as the Veterans Administration and the Selective Service whose costs are directly related to the military establishment were not accounted for in these original models since their services were free to the individual services and DOD.

Economic theory suggests that a thoroughly comprehensive model should include the imputed cost of removing a productive individual from the civilian labor force and placing him in the armed forces. If a plumber is drafted into the army and is utilized within his specialty his service pay would most likely be only a fraction of his civilian earnings. Historically, the military, using the draft system, has been accused of regarding labor, i.e., manpower, as a "free good" and thus using relatively more labor (compared to capital) than the "optimal" input mix. Some people argue that this is "cost effective." It may be in the Navy's point of view but on a grander scale, i.e., at the highest national level, it is highly unlikely.

In light of the President's advocacy of an All-Volunteer Armed Force as recommended by the recent Gate's Commission Report what will become of the once labor-intensive military as the cost of labor increases? Obviously before this question can be realistically answered one must know the costs of labor, i.e., there must exist a comprehensive personnel cost model. All costs attributed to personnel must be accounted for. Not only the common costs such as pay and allowances but also training costs, separation costs, and

retirement costs among others must be included. Estimates of retirement costs require prediction of reenlistments and perhaps a model of reenlistment rates would be required. With this background the researcher will now trace the important steps in developing an acceptable cost model offering criticism as the opportunity arises.

In examining the major modeling efforts no attempt will be made to validate the models or weigh their usefulness beyond their main purposes. The specific intent of examining these models is to investigate the general logic of the models. However, the final justification of any model rests in the results obtained. If reasonable answers to reasonable questions are obtained at reasonable costs the models developed are of value.

II. BILLET COST MODELING

A. PRAW 63-8/PRAW 63-22/PRAW 64-16

In 1963 the Navy set out to compute "enlisted personnel replacement costs." The subsequent reports, "Reports on Enlisted Personnel Replacement Costs," PRAW 63-8 and its supplement, PRAW 63-22 generated answers without specifying the underflying methodology. Then in 1964 Mr. Simon Arzigian, working for the Navy's Personnel Research Activity (PRA), completed a report (PRAW 64-16) on their methodology and the problems encountered in preparing PRAW 63-8 and PRAW 63-22. These three papers can be considered the initial papers of any consequence in personnel costing methodology.

Arzigian divided the personnel cost elements into six major categories as follows:

1. Procurement
2. Training
3. Pay and allowances
4. Transportation
5. Separation
6. General Support

Procurement costs were defined as those expenditures incurred by the Navy from the first contact with a prospective enlistee through to the time of the administering the oath of enlistment. Using figures obtained from existing reports on the cost of the procurement effort, the cost of recruiter vehicle amortization, and costs of Navy-owned, non-reimbursable spaces and then dividing this sum by the number of enlistments for the year an annual "Unit cost per enlistment" was obtained. In equation form,

$$\text{Unit cost per enlistment} = \frac{\text{Proc. cost+veh. amort + space cost}}{\text{Number of enlistments for year}}$$

It should be noted that this is an average cost and not a marginal cost.

Arzigian attempted to incorporate physical training facilities and training equipment into the training cost category. Needless to say there exists some difficulty in segregating the costs of operating and maintaining a training facility that is part of a larger base complex. The study used figures obtained from official reports on "Per Capita Cost of Training for Fiscal Year 19__" as compiled by the Bureau of Naval Personnel. These reports were specifically designed for Arzigian's needs. The original source documents were not presented in the report except as excerpts and therefore they could not be investigated thoroughly. In incorporating per capita costs of physical facilities Arzigian used a depreciation cost concept.

The federal government, unlike private industry, does not depreciate or amortize its capital assets in a manner which permits the determination of an annual valuation for these major cost items. In fact except in an accounting sense where one is seeking to gain a tax advantage there is no logical foundation for the depreciation concept since the cost of existing capital goods is a "sunk cost." Indeed the physical plant may grow in worth instead of "depreciating." Nevertheless, Arzigian felt some method must be utilized for incorporating the large costs of the physical plants and training equipment into the personnel cost model. Otherwise the large sums spent in buying expensive electronic training equipment for training electronics technicians would not receive any weight when comparing

the training costs incurred in training electronics technicians versus some group that does not require expensive training equipment. In order to incorporate the costs of these physical assets into the model a new concept called "utilization cost" evolved. The rationale was, if the government educated its personnel at civilian technical facilities part of the expense of the training process would account for the utilization of the training facilities plant and equipment. Thus there would exist a "utilization cost" attributed to each trainee. This concept allowed for an accounting of the cost of federally-owned plant and equipment to be incorporated in this early model. Obviously the utilization cost per trainee of plant and equipment is a function of the number of trainees per year.

There are some difficulties with this concept. The overall training cost would vary little as long as the number of students remained within the capacity of the plant and equipment, i.e., as long as there existed "slack" within the system. Specifically as long as the buildings were being less than fully utilized new students could be added with almost no additional expense incurred in these areas. But once the maximum capacity of existing facilities was reached a large capital outlay would be required and again slack would be introduced into the system. In this manner per capita costs would increase dramatically in a step-wise fashion after periods of relatively mild decreases.

Arzigian arrives at per capita costs for training facilities by dividing the initial cost of a building by its life expectancy to arrive at a yearly depreciation which in turn is divided by the number of students per year, i.e.,

$$\text{Per Capita Cost of a training facility (in a given year)} = \frac{\text{building cost}}{\text{life expectancy}} \times \frac{1}{\text{Nr. of students in a given year}}$$

No attempt was made to discount the building cost. Arzigian used the same technique in computing the per capita cost of training equipment, i.e.,

$$\text{Cost/man/week} = \frac{\text{Cost of equipment}}{\text{Life expentancy, in years}} \times \frac{\text{52 weeks/year}}{\text{Nr. of students using the equip in a given year}}$$

Again it should be noted that this is an "average" cost. Using these methods Arzigian was able to aggregate training costs to get training cost per student per week (for a given rate).

PRAW 64-16 also attempts to treat informal schooling through the use of "On the Job Training", (OJT). Skill level, a function of time, is accounted for as a decreasing step-function, i.e., a progressively decreasing amount of time is spent on OJT as the individual worker adapts to the job. Though Arzigian did not carry the idea much further, he stated that before any cost model was complete to his satisfaction, this factor would have to be examined relative to formal schooling. This is true if experience level is a factor in "replacement policy" and is considered explicitly. However, more philosophically, all of life is a learning process and the cutoff between training and doing is never clearly delineated and most likely varies from individual to individual. Each job performed yields some degree of training. In general, it would be extremely difficult to cost each and every job and attribute a portion of the cost to

training cost. Therefore it is considered a needless burden to account for OJT in the training cost element.

The pay and allowances category offered little difficulty. If a billet required a man with Y years service in paygrade X with certain specified professional requirements (and assuming an average number of dependents for the given pay grade) one could compute his "cost" from pay and allowances tables.

The fourth category listed in PRAW 64-16 was transportation costs. Transportation was partitioned into several subsets such as "home to recruiting station", "recruiting station to recruit training center", etc. Cost estimates, overall averages for various types of travel, were available from PERS H111, the Military Personnel Budget Division of BUPERS. Since any travel to the recruiting station is born by the enlistee or is hidden in the transportation portion of the procurement cost category it was omitted from the transportation cost category. Similarly, since costs of travel from recruit training to any other training facility are absorbed in the training cost category they were omitted from the transportation category to avoid double costing. Meaningful cost figures were derived for the other elements of transportation, e.g., "from recruiting station to recruit training center" was averaged out to be $122.69 while "transportation from recruit training center (or basic training school) to the first duty station" averaged out to $290.39 per man.

The fifth category, "separation", was also difficult to work with. Travel incident to separation was already accounted for in the transportation section. Other costs included in the separation category

included the terminal leave payment, pro-rated subsistence payment, and pro-rated quarters allowance, when applicable. An interesting aspect of separation costs is that they are incurred regardless of any immediate reenlistment on the part of the separatee. PERS H111 compiled average rates for unused leave costs and these were added to compute separation costs.

The last category, General Support, encompassed only medical support. This was another problem area. Hospitals are not necessarily a function of current manning level but part of the nation's overall preparedness. Again Arzigian resorted to the utilization cost concept and an average figure of $103.28 per man per year was computed. This figure was based on current average force strength and therefore did not account for retirees and dependents hospital use. Every man was "paid" $103.28 regardless of his dependent status. This did not reflect the increased usage of hospital facilities enjoyed by the more senior personnel with larger number of dependents.

In summary, Arzigian's initial model was comprehensive, put forth some basic ideas, and offered some insight into the problems to be encountered in billet costing. Philosophical questions were raised on government depreciation of physical assets and were handled using the utilization cost concept. The concept of marginal costing was not examined and all costs were treated as essentially linear with average per capita costs resulting. In assigning costs to fill each cost category matrix Arzigian used point estimates based on current data. This is acceptable if the model is to be applied to current systems. However, if the model is to be used

to predict future costs, an analysis of trends should be employed. Finally, it should be realized that Arzigian attempted to examine only Navy related costs and did not examine outside costs, such as retirement costs.

B. WRM 67-11

A report entitled, "Design of an Enlisted Personnel Cost Analysis System" by Jerome Bershtein was released as WRM 67-11 in October 1966. It was more detailed than previous reports and embodied "the latest refinements and procedures developed by the Personnel Research Laboratory since the "method" report published in 1964", i.e., PRAW 64-16.

The general approach of constructing a model enlisted person for each specialty was continued. Again, the data used in the model was of the "average per capita cost" form. The general cost categories remained essentially the same, however, they were expanded to include more detail. For example, within the aggregate category of procurements costs the following items were specifically enumerated:

a. Advertising and printing.

b. Travel costs of assigned and attached personnel; travel costs of applicants to the location of the execution of the oath of enlistment; and return travel of rejected applicants.

c. Vehicle cost of operation, maintenance, and storage.

d. Lodging and subsistence furnished applicants until departure from the place of enlistment.

e. Rent and utilities for leased property.

f. Other costs including the cost of communications, contract medical service, shipping, repair to office machines and equipment, office supplies, furniture, etc.

Similarly, training costs were more specifically identified. A modification was made in computing student costs. The aggregate cost of the school (less student pay and allowances) was divided by the total student weeks to yield an "average cost per student week" which in turn was multiplied by the course length to achieve "cost per student", i.e.,

$$\text{Cost per student} = \frac{\text{Total School Cost (less pay...)}}{\text{Total student weeks}} \times \text{Crs. length}$$

Pay and allowance computations were more explicit. Initially a rating profile was constructed from historical data. Specifics on how this was done were not given. It was not stated whether trends were analyzed or whether point estimates were used. For example, as World War II/Korean veterans depart the inventory via retirement, it is conceivable that more vacancies will occur at the top of the leadership pyramid and rate of advancement will increase. If point estimates were used a frozen picture would result and each rate and rating would be examined at only that instant of time to determine how long each man spent on each step of the advancement ladder. More properly trends should be examined in constructing the rating profile. All that is stated in the report is that an average time for each enlisted pay grade was computed for each rating. Using this rating profile and a cost figure for "Basic Pay" obtained from the Navy Comptroller Manual a cost figure was derived for each rating and grade. The Base Pay element listed in the NavCompt Manual is based on weighted averages for grade/rating and not only includes what is commonly referred to as basic pay but also encompasses basic allowance for quarters and basic allowance for

subsistence plus an amount representing the government's contribution to FICA. As a typical example, an ET1, Electronics Technician First Class, with 123 months service had received a total Basic Pay of $51,585.00. Other pay items were also specified and appropriate costs were computed using the rating advancement profile previously discussed. A more specific listing of these pay categories may be found in Appendix A of this report. In arriving at these cost figures for pay and allowances several assumptions were required. For example, the number of months of entitlement to special pays such as sea pay was estimated from historical data. In arriving at costs for reenlistment bonuses a cycle or pattern of reenlistment terms was used. In this case a 6-4-6-4 pattern was assumed, i.e., first enlistment contract was assumed as six years, second as four years, etc. This was done for simple convenience and without recourse to historical data. Similarly, in the case of Family Separation Allowance an educated guess was made as to the length of entitlement. Even though these methods appear crude it must be pointed out that in many cases sufficient records were not available at the time this work was being carried out.

Computation of the reenlistment bonus was probably the most complex task even with the simplifying 6-4-6-4 assumption. This was caused by the then newly instituted variable reenlistment bonus being added to the regular reenlistment bonus. Again a rating advancement profile was used. The myriad of tax concessions offered to bonus recipients inside the Vietnam combat zone complicated the data and it is uncertain after reading the report how, if at all, this aspect was dealt with. Since new rates are added to the eligibility

list for the variable reenlistment bonus annually while some are deleted it is not sure how it is proposed to handle the resulting data. This was not a problem in 1966; however, it was foreseeable, and has been a problem since.

Separation costs, transportation costs, and general support costs were computed essentially as in the original Arzigian work. In summary, Bershtein's report added little to the existing methodology but it did improve on Arzigian's original work by filling in some of the missing data. Still the model contained only those enlisted personnel costs directly incurred by the Navy.

C. WRM 67-18/WRM 67-31

By December 1966 PRL had produced another paper, WRM 67-18, on what they envisioned as the direction to be taken with their developing cost model. Their previous work was receiving varying degrees of acceptance at all levels within the Navy Department as the standard for military personnel cost models. It was also receiving some acclaim from other DOD activities.

WRM 67-18, written by Mr. Roy Gettings, reviewed the inputs and outputs in the personnel cost system and spoke of developing a computerized cost model. Mr. Gettings foresaw an open system where different questions could be asked of the model and as long as the initial model assumptions were not violated reasonable answers would be generated. He envisioned the expansion of the Navy model into an all-service model with very little modification required. The major obstacle was the lack of inter-service standardization, e.g., amortization schedules of real property differed. In

constructing the input data banks one of the major decisions to be made would be whether to continue the "model man" approach or, if the capacity of the computer permitted, go to the more accurate, though more complex, individual basis. The individual basis would reduce a large degree of statistical analysis and remove unnecessary assumptions, but Gettings foresaw the mass inputs available on the horizon through "Joint Uniform Military Pay System" (JUMPS) and the "Naval Manpower Information System II" (NMIS II).

The major changes in converting the existing Navy model fell into three categories. First, as cited previously, the support category was weak in inputs, containing only per capita medical costs. Secondly, training costs required greater investigation and standardization, e.g., BUMED school costs were computed differently than the BUPERS school cost at the original source documents. Thirdly, the new input data would need to be verified for compatibility with the system.

Gettings followed WRM 67-18 with WRM 67-31, "Proposed Content of an Officer Personnel Cost Model." Though not a quantum leap in methodology this appears to be the first major work done in officer personnel cost modeling. Almost all previous work in officer personnel cost modeling was fragmented and solely oriented to the procurement costs or at most costing of the officer training process up to the point of commissioning. In many respects the ground work laid in enlisted personnel cost modeling was immediately applicable to officer cost modeling with only minor changes required.

Gettings' proposed officer model included the same six categories for the enlisted model with the following differences listed by him:

a. Separation of precommissioning and post commissioning costs.

b. Minor shuffling of pay and allowances cost categories, e.g., officers do not receive sea pay whereas enlisted do.

c. A larger input of source material would be required for officer procurement due to the variety of methods in use.

Gettings also cited three areas of general weakness in personnel cost modeling and suggested further research in these areas:

a. Expansion and clarification of personnel support costs.

b. Expansion to include non-Navy costs, e.g., retirement costs.

c. The development of formulae to pro rate or amortize over the expected period of personnel retention.

As is evident the prime mover in the field of personnel costing during the early sixties was the Navy's Personnel Research Laboratory. It was primarily for this reason that when the Secretary of Defense in early 1967 decided to seek a DOD/all-service personnel cost model he tasked the Navy to perform the work.

D. OP-96, SYSTEMS ANALYSIS DIVISION, OFFICE OF CNO

LCDR James L. Fitzgerald working in the Office of the Chief of Naval Operations, Systems Analysis Division, developed a billet cost model in January 1969 that differed in concept from previous studies. LCDR Fitzgerald attempted to consider manpower costs as separate from systems cost. He emphasized sensitivity studies on retention rates as a factor in personnel costs. He also pointed out that the use of average personnel costs can be quite misleading, e.g., in the area of retention average values do not depict a full picture since

the variability of retention rates is supposed and rates of retention are highly interrelated with personnel costs. Retirement costs and basic pay costs increase with increasing retention while training costs fall.

In defining billet costs Fitzgerald explicitly defined a billet as "a position or assignment which is filled by one person" and continued by stating that "the value of resources required to develop and maintain a man at the skill level required by the rating and pay grade assigned a billet is the billet cost." In essence, this formalized the concept envisioned by others but never so explicitly stated. Fitzgerald returned to the fundamentals and documented the unspoken concepts that were the foundations of a billet cost model. He put his finger on the heart of the matter when he formulated the basic equation,

$$\text{Billet Cost (in yr. i)} = Ui + Ai \frac{(\sum Dj)}{(\sum Tj)}$$

where Ui is the operational costs expended on a man during an operational billet year, i.

Ai is the man's operational availability in year i.

Dj is the cost expended during non-operational time in the jth year, j equals 1, . . . , n.

Tj is the operational time during the jth year, j equals 1, . . . , n.

n is the total career time.

This equation is a subtle departure from the PRL model since all costs were converted to annual costs, e.g., separation costs were pro rated back over previous years service while procurement costs were amortized forward over subsequent years of service. Thus costs incurred by a man during a non-operational status were charged

to future operational periods and, in summary, value and experience level were more accurately attributed to future billets. In programming this model for a computer solution, Fitzgerald utilized existing attrition (or retention) rates gleaned from the BUPERS Master Tapes to derive a normalized cohort flow model, i.e., a cohort entered the career pipeline at time zero and underwent attrition at the then existing rate each year until at time n, the end of career epoch, only one member of the cohort survived to retire.

Fitzgerald's model was more mathematically sophisticated than previous models and thus was more difficult for a layman to follow. The most interesting aspect of the model was the handling of retirement costs. It was assumed that an annual installment was paid to a retirement fund during each year of a career. The fund received annual interest at an unspecified rate of S percentage while the amount paid to the retiree escalated at an unspecified rate R percentage each year. Letting B be the initial amount of payment and N be the expected number of payments the principal value of the fund at retirement, $PVAL_1$ equalled

$$B_1 \frac{(1 + S)(1 + R/1 + S)^N - 1}{1 - (1 + S/1 + R)}$$

This value represented the annual retirement contribution for each retiree. Fitzgerald continued this approach to cover the contingency where 1, the career length, exceeded twenty years. Using various estimates for the generally unpredictable parameters R and S he could conduct a sensitivity analysis on the retirement cost effects.

Fitzgerald also attempted to carry the personnel cost concept into the realm of effectiveness. Owing to a lack of an accepted

standard of effectiveness of personnel within the military establishment, his efforts were doomed to failure. A point neglected by Fitzgerald, perhaps due to the mathematical complexity that might have been added to his model, was the interest cost on investment in human capital. However, in order to reflect any gap between training and utilization Fitzgerald's simple model would have to be expanded at the expense of mathematical simplification.

E. B. K. DYNAMICS BILLET COST MODEL

In May 1968 B. K. Dynamics (BKD), a private consulting firm, submitted a cost proposal for the development of a billet cost model. Previously they had been active in personnel costing in their efforts on the DX/DXG project and in the ASW Force Level Analysis. On 25 June B. K. Dynamics was formally awarded a contract that called for a review of the state of the art relative to military manpower/personnel cost analysis and more importantly to design a Navy Manpower/Personnel cost analysis system. In performing this task they were specifically charged with identifying present and future anticipated output requirements, determining raw data inputs, determining non-cost manpower statistical data items, determining updating requirements, and, finally, developing computer hardware specifications and alternatives.

In August the state of the art requirement was completed and submitted. The rather sketchy report highlighted the major inadequacies of previous work, namely overspecification and lack of standardization. The report cited these points as leading to distrust of the entire cost analysis concept at many levels of higher command

and extreme difficulty in making systems comparisons. Implicit here is that arbitrary standards might be better than no standards since some common basis was needed in comparing systems. B. K. Dynamics also cited the need for detailed identification of cost apportionment between government echelons. To alleviate confusion BKD segregated costs into three categories, Navy costs defined as those costs budgeted for by the Navy, DOD costs as those costs budgeted solely at the DOD level, and U. S. Government costs as those defense related costs budgeted by the federal government less DOD and Navy costs. B. K. Dynamics also cited the differences between the evolving billet cost model and the then recently defined per capita cost concept. Until this point in time there appeared to be a blending of concepts which at times resulted in confusion. The billet cost concept as defined by Fitzgerald still held. A per capita cost model would emphasize the life-cycle cost of a man in the service vice a billet within the system. No conscious effort appears to have been made up to this period except as fallout from billet cost modeling.

In examining the Navy Manpower Data System it was noted that the acquisition of data was on "an as-required-basis." As the need arose data was gathered. The data so gathered was essentially current data and was in general only valid for the current period. In general, historical data, if available, was poor. Trend analysis was almost non-existent. In evaluating the then current system status BKD found that the most useful portions of the system were the personnel data base and what they termed the "cost-function models" which they defined as "the general way in which the current state of the art in cost analysis and manpower analysis are combined

to generate personnel costs." In their opinion these were only considered "good" while all other facets faired less well.

In designing its cost data bank, BKD attempted to maintain a degree of flexibility in order to expand beyond the pure Navy cost model and to allow for growth into the needed DOD cost model. In addition to this flexibility BKD attempted to incorporate the means of using alternate methods of costing the specific cost categories. For example, training costs could be spread over all subsequent years or scaled down to zero at some career point further downstream. BKD also attempted to incorporate static models for current force level costing and dynamic models for trend analysis for predictive work.

An officer and enlisted model were developed in parallel, and similarity between models was attempted throughout. Officers don't draw sea pay, yet to keep the models similar a module was provided and the matrix was filled with zeros to represent the lack of officer sea pay.

In general, the computer model built by B. K. Dynamics utilized matrix methods. Modules for each main line data element (MLDE) were matrices of size N X R, where N equalled the number of years of career length and R equalled the number of ratings or designators. In certain cases these N X R matrices were replaced by a single-valued vector. For example, certain costs were constant without regard to length of service or rating. In those cases computer storage was saved by matrix reduction. Each main line data element had an associated subroutine to compute the necessary elements to fill the matrix. The procurement MLDE had nineteen separate inputs

from "recruiter training costs" through to "general support, applicant lodging and subsistence." In all, thirty separate MLDE were defined and they essentially followed the breakdowns within categories of previously done studies. In certain cases they were expanded to allow for easier manipulation. The pay and allowance category was divided into fourteen MLDE from base pay and FICA through to clothing allowance. The rating profile technique was used in computing expected base pay for year i. Similar devices were used to cost out all pay categories. The work of previous studies is evident. BKD did encounter difficulties in the same areas that gave previous researchers problems, i.e., training costs and retirement costs.

They examined retirement costs three different ways and developed appropriate computer subroutines for each method. In each case a retirement benefit, R.B., was computed first.

$$R.B. = \sum_{i=1}^{LE} Pi\,(1-D)^{i-1}(1/E)^{i-1}$$

where LE is life expentancy, years of life remaining after retirement, an expectation in the acturarial sense.

Pi is the annual pay for year i.

D is a discounting factor, assumed constant and not specified.

E is an escalation factor, assumed constant and not specified.

Given this retirement benefit three methods of apportionment were devised.

a. Percentage of base pay

$$TBP = \sum BP_j$$

$$F = \frac{R.B.}{TBP}$$

where TBP is Total Base Pay, F is the fraction R. B. is of TBP, and F x BPj is the fraction of the jth years base pay charged to the jth year as the retirement cost.

b. Equal annual installments

$$A = \frac{R.B.}{N}$$

where N is the expected career length, e. g., thirty years and A is the annual installment of retirement benefit charged to each career year.

c. Payment proportional to the probability of retiring

$$\sum_{i=1}^{N} Pi = S$$

$$Fj = \frac{Pi}{S}$$

where Pi is the probability of going on to retirement from year i and Fj is a fraction charged to the jth career year.

The percentage of base pay was recommended for no apparent reason other than one method was all that was required as a standard and the payment proportional method was frowned upon since it added relatively high costs to the senior billets since they contained the personnel most likely to continue in the Navy until retirement. Following BK Dynamics suggestion, the Chief of Naval Personnel, who was officially responsible for developing a billet cost model for the Secretary of the Navy, standardized retirement cost computation in

March 1969 by adopting the percentage of base pay method.

The other prime problem area, training costs, revolved around the determination of the most effective method to handle building costs. In all other respects the previously developed methodology was followed to some degree. In attempting to solve the building cost aspect of training cost BKD offered three methods for consideration, amortization plus operation and maintenance, operation and maintenance alone, or utilization cost based on square feet of floor space utilized, building type, and geographic location. BKD claimed all three offered special merits and then recommended using operation and maintenance costs alone. This was not justified in BKD's reports but the rationale probably centered on the discussion of depreciation cost concepts cited at the beginning of this paper, i.e., building cost was essentially a sunk cost that could possibly be recovered by disposing of the building or alternatively converted to some other purpose other than a facility for conducting training course X. The operation and maintenance method is more preferred in systems analysis work. Many minor problem areas were found during BKD's efforts. Data retrieved from OP-05 with regard to naval aviation training was not of acceptable quality. In addition, BUMED admitted difficulty in retrieving medical training costs for certain training conducted at non-training facilities, e.g., at hospitals where the courses were technique-oriented vice equipment-oriented. Also, it was difficult to retrieve data where the equipment utilized was operational equipment vice specifically designated training equipment.

In summary, B. K. Dynamics attempted to gather in all the loose ends, tie everything together, and then computerize the resulting

model. Their work appears comprehensive with only minor exceptions. For example, there still exists difficulty in accounting for team training in the model, there is no accounting of training received by reserves prior to reporting for active duty, and warrant officers are no where accounted for in either the officer or enlisted segments of the models. It has been learned that B. K. Dynamics model has been officially accepted by the Navy for implementation. It should prove an asset to systems analysis but it should be emphasized at this point that inherent in these models are certain assumptions concerning the relative status quo. Major changes to the defense establishment, such as zero-draft, may affect billet costs more than the internal parameters can account for. The model, though accepted for Navy use, must still be developed further for all-service use and possible DOD use.

III. BUDGET COST MODELS

A. GENERAL DISCUSSION

The history of budget cost models is somewhat easier to follow, although there are no references one can refer to that give "the" model used in budget costing. Historically PERS H, the comptroller division of BUPERS, has been instrumental in preparing the "Military Personnel, Navy" appropriations requests. Recent telephone conversations with that organization reveal there is currently no "model", no computerized methodology for aggregating all the components of MPN. In essence, standard statistical and cost accounting techniques are applied by PERS H practitioners to massage the data and arrive at MPN budget requests in light of predicted force reductions or increases, changes in advancement patterns, base closures, etc. Since the appropriation "Military Personnel, Navy" amounts to one-quarter of the Navy's total appropriations, and is therefore a figure in the billions of dollars, there has been recent interest in shortening the time needed to predict budget cost changes. In order to better understand what is involved a more detailed examination of MPN appropriation is required.

The Military Personnel, Navy appropriation provides for pay, allowances, subsistence, clothing, permanent change of station travel (including all facets such as serviceman's travel, dependent's travel, transportation of household goods, etc.), and other costs such as mortgage payments, employer's contribution to Social Security, etc. It is readily noticeable that several of these categories were required in billet cost modeling. Noticeably absent however

are training costs and retirement costs, those items that made billet costing so difficult. Another difference is MPN is immediately influenced by several factors such as force composition, force strength, force deployment, and force turnover or retention. Inflation is of course a factor in both but more predictable in the short term predictions of budget cost modeling.

Since MPN is a major category within the Navy's budget it is appropriated by Congress as a total figure. The appropriation is however, justified under a number of basic budget activities such as pay and allowances, subsistence-in-kind, etc. All active duty personnel, including officer candidates and midshipmen, are provided for in the necessary computations. By far the dominating category within MPN is the pay and allowance category which accounts for approximately ninety percent of the appropriation. Subsistence-in-kind and movements, permanent-change-of-station, account for slightly less than ten percent in about equal amounts whereas the activity "other costs" takes the remaining approximately one-tenth of one percent. The entire appropriation is handled under open-allotment procedures; meaning no unit activity is specifically limited in its disbursements, but, in the aggregate, the Navy must stay within its appropriation. (With the introduction of the Resource Management System into the operating fleet every unit may eventually be held accountable for its portion.) Needless to say under the present system, management is presented with a highly complex task. In particular, since many allowances such as quarters allowance and family separation allowance are hinged to a dependency status where average dependency figures can produce gross dollars and cents

errors from actual disbursements, it is a tribute to the Navy's personnel managers that MPN has never been overexpended though it is realized this in itself does not indicate optimal management practices.

Cost reductions can be implemented by reducing permanent change of station movements but what does this do to effectiveness? Does the prospect of continual sea duty without prospect of shore duty have a bearing on the morale of today's sailor who incidently may be a husband and father? To what degree does morale influence effectiveness? Answers are needed to these and similar questions before today's cost reductions can be translated into cost effectiveness. Increased retention may increase MPN since pay and allowances are directly tied to length-of-service. Even though increased retention might decrease training costs considerably it is necessary to recall that training costs are not a part of MPN in any direct sense.

In summary, the actual dollars allocated within the Navy's budget for personnel expenditures fall largely within the Military Personnel, Navy appropriation category. Navy's personnel managers face a ticklish problem in dollars and cents personnel management in an era of rapidly changing ideas. Former methods of appropriation computation though adequate in the past seem inadequate to meet today's rapid response decision making.

Two recent proposals for budget cost models will now be briefly examined. One is the appropriation-oriented cost model proposed by B. K. Dynamics, the recent contributor of the successfully adopted billet cost model examined earlier, while the second is the Navy's own BUCOMP (Budget Cost Management Program).

B. B. K. DYNAMICS' BUDGET (APPROPRIATION-ORIENTED) COST MODEL

B. K. Dynamics in January 1970 proposed an "Appropriation-oriented Cost Model Design" that was intimately related to their then under development billet cost model. In order to accomplish the rapid development of a computerized budget model it was envisioned that the manpower cost data bank would have to be modified to deleting those billet cost categories that did not apply to budget costing of MPN or other personnel budget related items.

Each subroutine of the billet cost model was examined and those subroutines that required modification for appropriation-orientation were identified. Those sections of the computerized billet cost model that were not utilized in the appropriation-oriented model included the sections on School and Training Costs, Procurement Costs, TP&P Costs, and "downtime" Costs. It will be recalled that School and Training Costs as well as Procurement Costs were derived through an amortization scheme over future years and as such had little meaning in the dollars and cents fiscal costing of the budget year under consideration. Similarly TP&P costs, i.e., those costs related to Transients, Patients, and Prisoners considered a "lost" cost in the billet cost model, and "downtime" costs were essentially devices used to increase billet costs for "non-operational" downtime.

It was also determined a modification would be required to the output section of the billet cost model to properly consolidate and display the budget costs. The change from a simple billet cost model to a billet cost model with an appropriation-oriented capability would add about ten percent to the storage requirements needed. As a

further demonstration of the immediate feasibility of the increased capability of the new model it was predicted that the only additional reporting requirement imposed on the reporting activities would be the requirement of breaking down their reported costs by appropriation head and appropriation subhead.

The approach presented by B. K. Dynamics is reasonable. In particular since their billet cost model has been accepted for implementation it seems highly desirable and completely feasible to test their appropriation-oriented cost model for possible adoption by the Navy's budget managers.

C. NAVY's BUDGET COST MANAGEMENT MODEL (BUCOMP)

Simultaneous with the development of B. K. Dynamics' budget model, the Naval Personnel and Training Laboratory had been developing a computerized model of their own which would be compatible with their ADSTAP System (Advancement, Strength, and Training Planning System). Initially the concept of BUCOMP originated as a force costing model linked to the strength planning subsystem of ADSTAP. It soon became evident that the simple budget model then in use, which contained only enlisted pay and allowances, was inadequate. It was necessary to incorporate the whole MPN into the model to properly cost any desired strength plan.

Immediate research efforts were directed at the expansion of BUCOMP by adding subroutines for officer pay and allowances as well as midshipmen pay and allowances plus the remaining MPN items. Several subroutines were developed to compute the various pay categories and, in the case of their DOLCOMP routine, a subroutine

was developed to produce a force structure given a dollar constraint. BUCOMP, MOD II, the most recent version, encompasses the whole budget package. It is an ambitious program but like any computer model it is only as good as its inputs. The inputs will be essentially those developed by PERS H. Until further refinements are made in the model and its inputs, only first-order approximations will be available as output.

D. BUDGET COST SUMMARY

Both budget models reviewed offer, in many instances, the same benefits. Both methods are proceeding along relatively identical paths. The Navy faces a buyer's market wherein they will have to make a choice between the two models offered. Both offer the advantage of being compatible with some system-in-being. Other ramifications must be investigated, including implemention costs, before an intelligent choice can be made. It is believed, however, that it is in this area of implementation cost that BUCOMP has an advantage. Since it was developed in a Navy laboratory a great deal of its cost has already been met. Still, it is difficult to judge at this point in time which has more merit without further study. It is possible that both models might be totally compatible and interchangeable. The main obstacle remaining is model validation and testing, i.e., does the model give realistic answers? The Navy appears to be in the enviable position of being able to force a "run-off" between the two software systems. In any event, rapid response budget costing appears to have arrived.

IV. A PROPOSED PER CAPITA COSTING MODEL

With budget costing and billet costing almost solved what personnel costing remains? In the very recent past questions have arisen on the "life-cycle" costing of personnel, i.e., "Without regard to "uptime" and "downtime" what is a reasonable figure to expect to expend on an individual during his "service life" and beyond?" Initial impressions are that this is the problem originally envisioned as the billet cost concept prior to Fitzgerald's definition. This appears to be true. In fact a Per Capita Cost Model (PCCM) can probably borrow from the storehouse of knowledge gathered during the development years of both billet cost models and budget cost models. It is feasible to convert B. K. Dynamics' billet cost model into a per capita cost model with relatively little time and effort.

Initial requirements levied by BUPERS in November 1970 called for a model compatible with ADSTAP. Further requirements specified that a 9X31 man-year costing table for each naval rating be produced. The 9X31 matrix conforms with the nine enlisted pay grades, E1 to E9, and the 31 to the thirty-one length-of-service categories, 0 to 30. A further stipulation was that the system developed be a restructuring of the billet cost model and also be able to be implemented on BUPERS IBM 360-65 computer system.

An approach recommended by the researcher is to examine the billet cost model and disaggregate where necessary to extract the fundamental data needed for per capita costing. In particular, the uptime/downtime scheme for amortizing training costs to operational billets must be removed. Further, those costs presently carried for

a twenty-five year career must be extended to the thirty-one year mark. This will effect the amortization of school costs, travel costs, and reenlistment bonus cost elements. Much of the data presently used in the billet cost model can be directly converted to the PCCM. Specifically nine of the fifteen billet cost model subprograms apply directly. Items such as base pay, FICA, and those costs that are either constant with respect to grade or constant with respect to year can be directly transferred. Other items such as hazardous duty pay, proficiency pay, and school and training costs must be distributed to the specific ratings. Certain ratings being more likely to draw larger amounts of these than others.

The actual task itself is more complicated than the concept but it is evident that the billet cost model can be utilized to produce an acceptable per capita cost model without major difficulties.

With this system of models and any requisite fine-tuning the Navy should have a complete personnel costing system to meet their needs at present and in the foreseeable future. The modular approach used in developing the subroutines provides flexibility for changes as they develop while the capability exists for complete compatibility with force strength projection models allowing for rapid response costing for decision makers to plan today's and tomorrow's Navy.

APPENDIX A

MILITARY MANPOWER COMPENSATION

BASIC PAY - Pay, as prescribed by Public Law, received by active duty personnel. A function of pay grade and length of service (l. o. s.).

BASIC ALLOWANCE FOR QUARTERS (BAQ) - Money received in lieu of assignment to public quarters. A function of pay grade, and in the case of enlisted personnel dependency status and time-in-service. Non-taxable.

BASIC ALLOWANCE FOR SUBSISTENCE (BAS) - Money received in lieu of subsistence-in-kind. In general, for officers a fixed amount per month and for enlisted a function of messing facilities prescribed. Non-taxable.

CLOTHING ALLOWANCE - For certain officers such as those of reserve components, ROTC graduates, and enlisted members appointed as temporary officers a once-only clothing allowance is granted. Enlisted personnel receive an initial issue of clothing upon entrance and thereafter a monthly uniform allowance is granted for repair and/or replacement.

PHYSICIANS, DENTIST, AND VETERINARIANS PAY - A special pay in addition to all other pay received by medical, dental, and veterinarian officers. This pay is not received by several of the other medical arts, e. g., podiatrists. A function of classification and length of service.

HOSTILE FIRE PAY (COMBAT PAY) - Special additional pay received by personnel ordered to and serving in designated hostile fire areas.

SEA PAY - A special pay given to enlisted personnel assigned to ships or shipboard staffs. A monthly pay varying by pay grade.

FOREIGN DUTY PAY - A special pay given to enlisted members on duty outside the continental limits of the United States in areas designated by the Secretary of Defense. The same rate as prescribed for sea pay is used; however, an individual can not receive both.

INCENTIVE PAY (HAZARDOUS DUTY PAY) - An extra pay received by personnel assigned to hazardous duty such as flying, submarine operations, demolitions, parachuting, etc. Generally $110 for officers and $55 for enlisted personnel, except in the case of flying and submarine duty where the rate structure varies according to pay grade.

PROFICIENCY PAY (PRO PAY) - An additional pay awarded by the Secretary of Defense either as specialty pay or superior performance pay. Designed to retain highly skilled personnel whose specialty is short in supply and/or whose training is long and costly. It is a monthly pay graduated into specialty levels. The list of eligible specialties is promulgated annually.

FAMILY SEPARATION ALLOWANCE (FSA) - An additional monthly pay designed to either compensate a man for maintaining two sets of quarters, when prescribed, or to aid in defraying additional household expenses when separated from dependents for long periods of time, i.e., greater than thirty days. Paid to personnel entitled to BAQ.

REENLISTMENT BONUS - A special cash bonus paid to enlisted personnel upon reenlisting. A function of the number of the reenlistment, e.g., 100 percentage for the first, 16.66 for the fourth and subsequent, monthly base pay, and number of years of the reenlistment contract. The sum of all reenlistment bonuses received by an individual in a career can not exceed two thousand dollars.

VARIABLE REENLISTMENT BONUS (VRB) - A special reenlistment bonus supplemental to the regular reenlistment bonus. A multiple, promulgated annually, is associated with the skills that are scarce and/or expensive to replace. The VRB list does not necessarily agree with the Pro Pay entitlement list. The prescribed multiple is multiplied times the regularly entitled reenlistment bonus and then the resulting product is added to the regular reenlistment bonus to give the total reenlistment bonus. This VRB entitlement is for first reenlistments only. The maximum total bonus can not exceed ten thousand dollars. If the reenlistment occurs during a month when the reenlistee is also entitled to Hostile Fire Pay the entire bonus is tax free under current regulations.

OTHER COMPENSATION -

a.) Employer's contribution to FICA - The U. S. Government as the employer of armed forces personnel pays the normally prescribed contribution to Social Security required of most employers.

b.) FHA Mortgage Insurance - The Government pays the monthly mortgage insurance charge of 1/2 of 1 % on all FHA mortgages of eligible active duty personnel.

c.) Servicemen's Group Life Insurance (SGLI) - The Government pays the "extra-hazard" premium of SGLI.

d.) Interest on Deposits - The Government pays interest on deposited money of personnel assigned to oversea duty. The deposited money must be deposited with a Uniformed Services disbursing officer. Current interest prescribed is ten percentage.

There are several other categories of military compensation but they are insignificant to the costing of pay and allowances and are therefore omitted here.

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13. ABSTRACT

The recent history and development of military manpower/personnel cost models is surveyed. The major models, in general those models not developed ad hoc, are traced in their development and examined for their consistency of logic. Both billet cost models and appropriation-oriented (budget) cost models are discussed with a sufficient background to discern their possible uses. In addition, a per capita cost model is proposed from the recently accepted billet cost model designed by B. K. Dynamics, Inc.

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